Can transient loads occur internally in a planetary gearbox?

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Can transient loads occur internally in a planetary gearbox?

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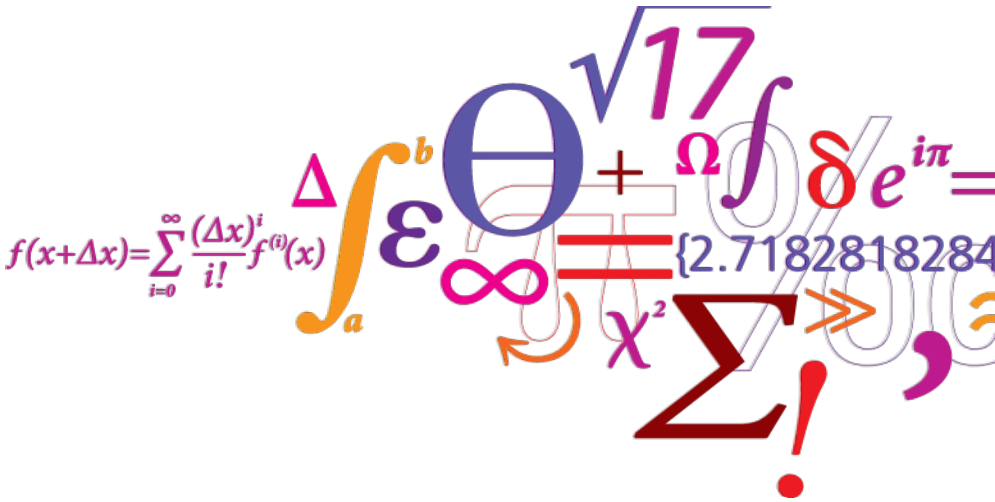

DTU Wind Energy
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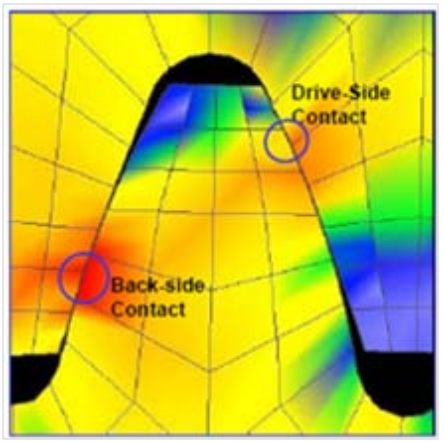
Introduction

- **The simple answer is “YES”**
- **if double contact can occur**



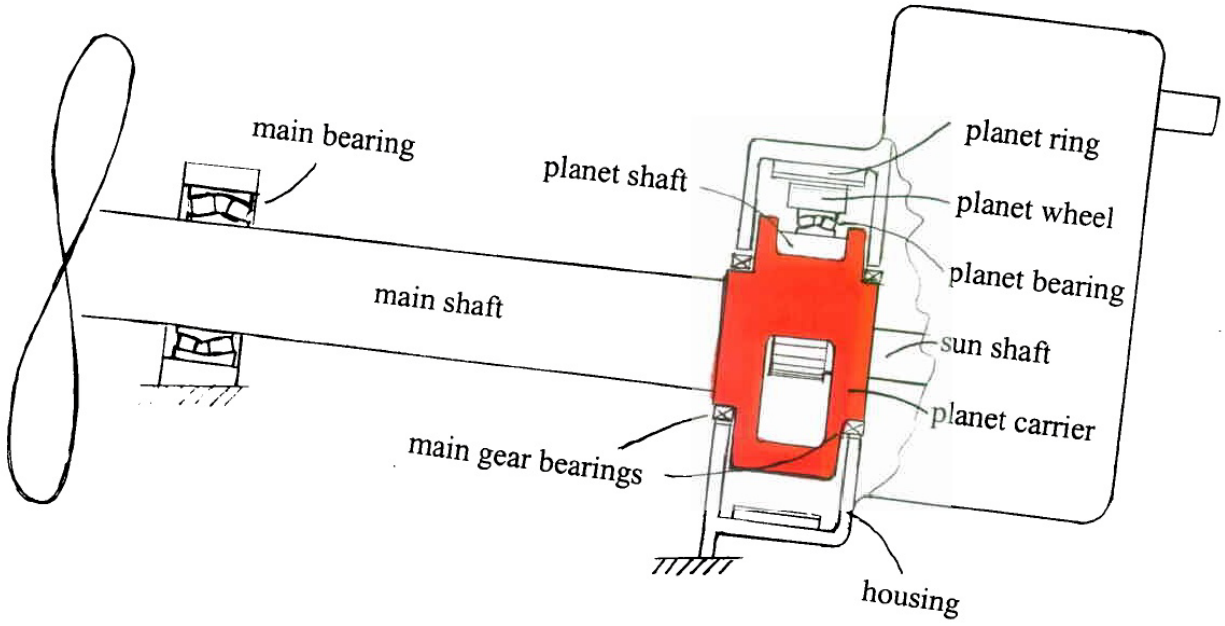
Double contact where the tooth backside is also in contact.

History

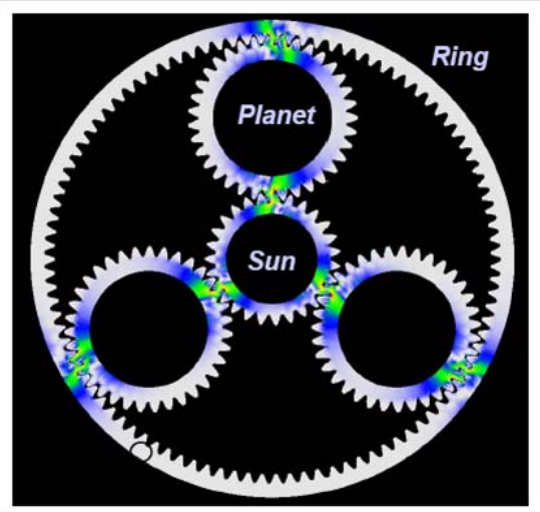
- Gear box failures discovered > 10 years ago on 600 – 800 kW turbines
- Modeling gearbox dynamics as an integrated part of turbine aeroelastic response in HAWC2 and look for explanations
- Concept with gearbox acting as second main bearing

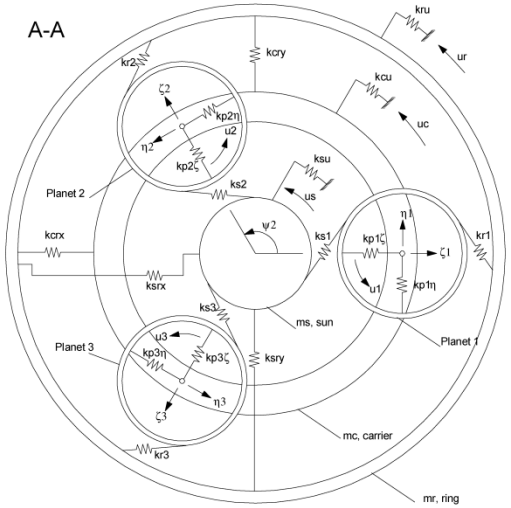
Mysteries or rumours?

- “Bearings on planetary wheels were the first to fail”
- “Replacing and doubling bearings made them last, however, caused the planetary ring to be warn out”
- “Planetary carrier bearings in some cases had high clearance”
- “Also high speed shaft bearings failed”
- “Big difference in gearbox lifetime for turbines in the same wind farm”
- “You could replace a broken gearbox for a turbine in a wind farm with exactly the same type, and then in some cases it would last”



Normal load pattern, Modelling in HAWC2





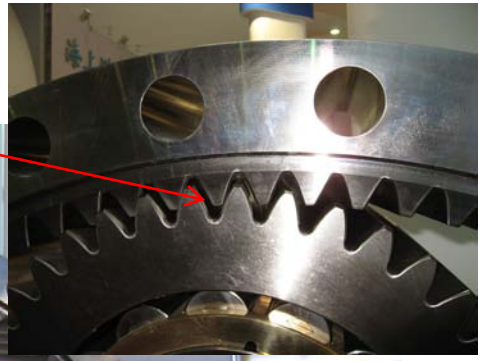
Load pattern during normal operation with drive side tooth contact only

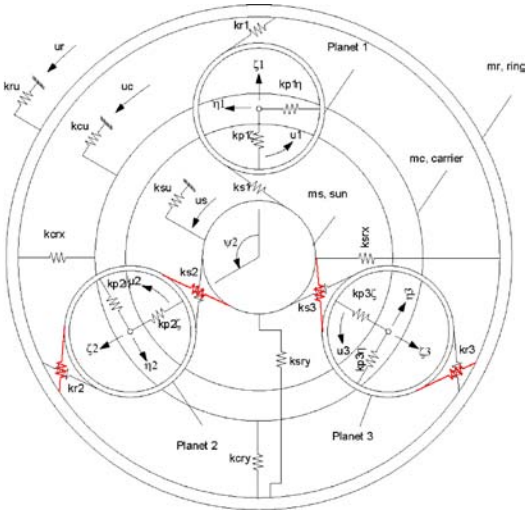
2-dimensional model with lumped springs representing tooth and bearing stiffness.

Conclusion:
Floating sun eliminates impact of external loading

Double contact, modelling in HAWC2

Clearance ~ 2mm



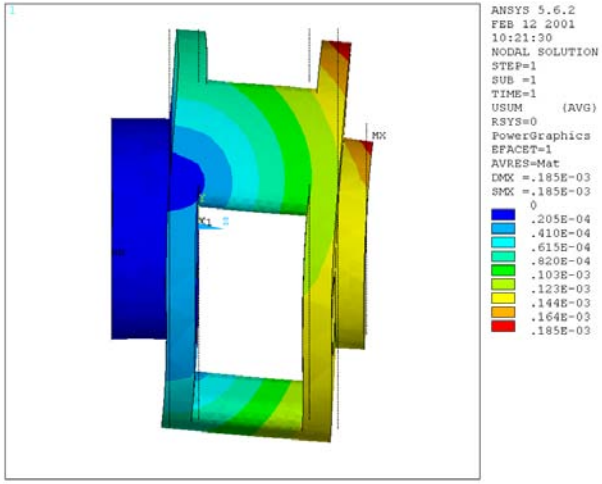


Double contact - the sun can be "caught" by two planets causing an uneven load distribution

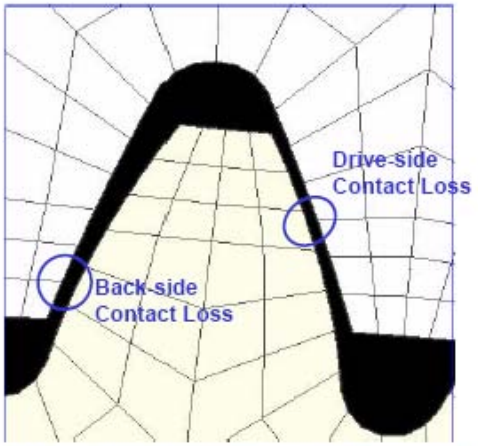
Carrier bearing clearance could cause double contact

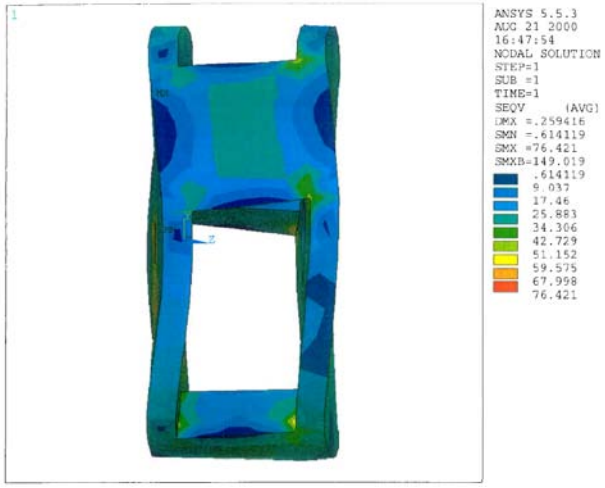
Tooth contact variations

Deformations and bearing clearance causes tooth contact variations

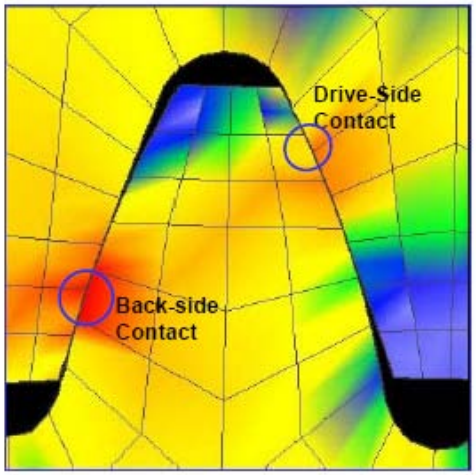


Tooth contact loss



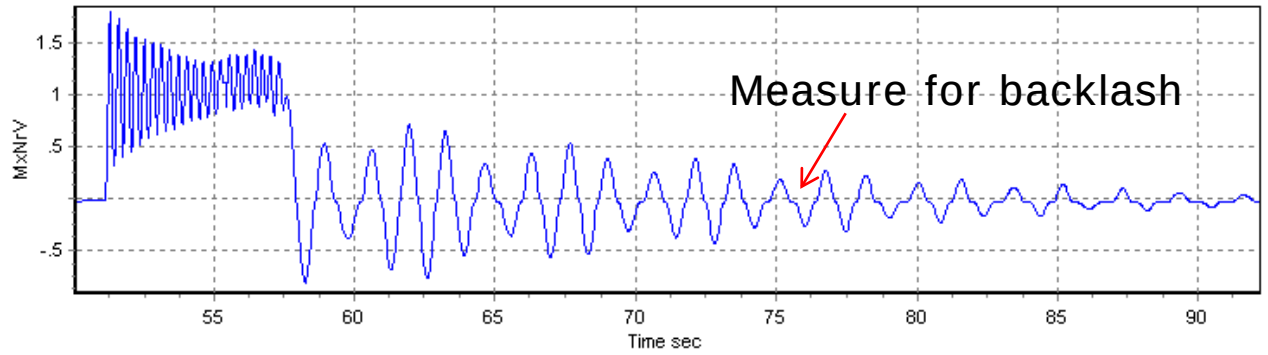


Tooth double
contact or wedging

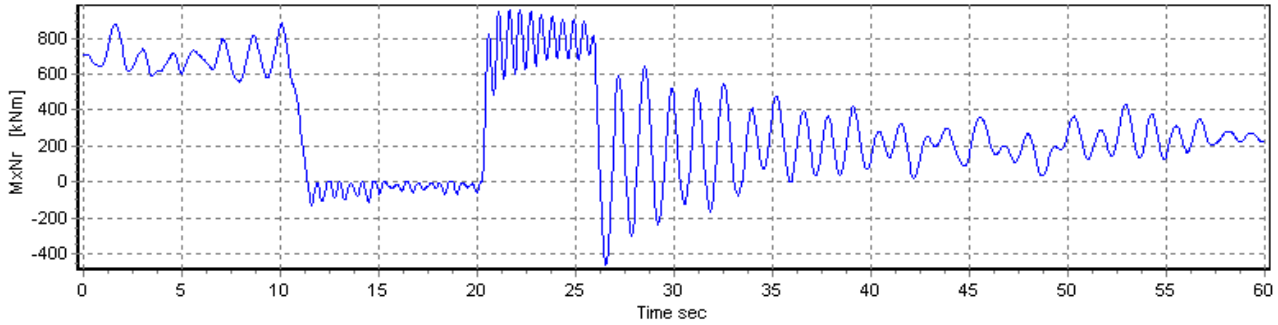


Braking sequence to reflect backlash

Shaft torque for NKT 500

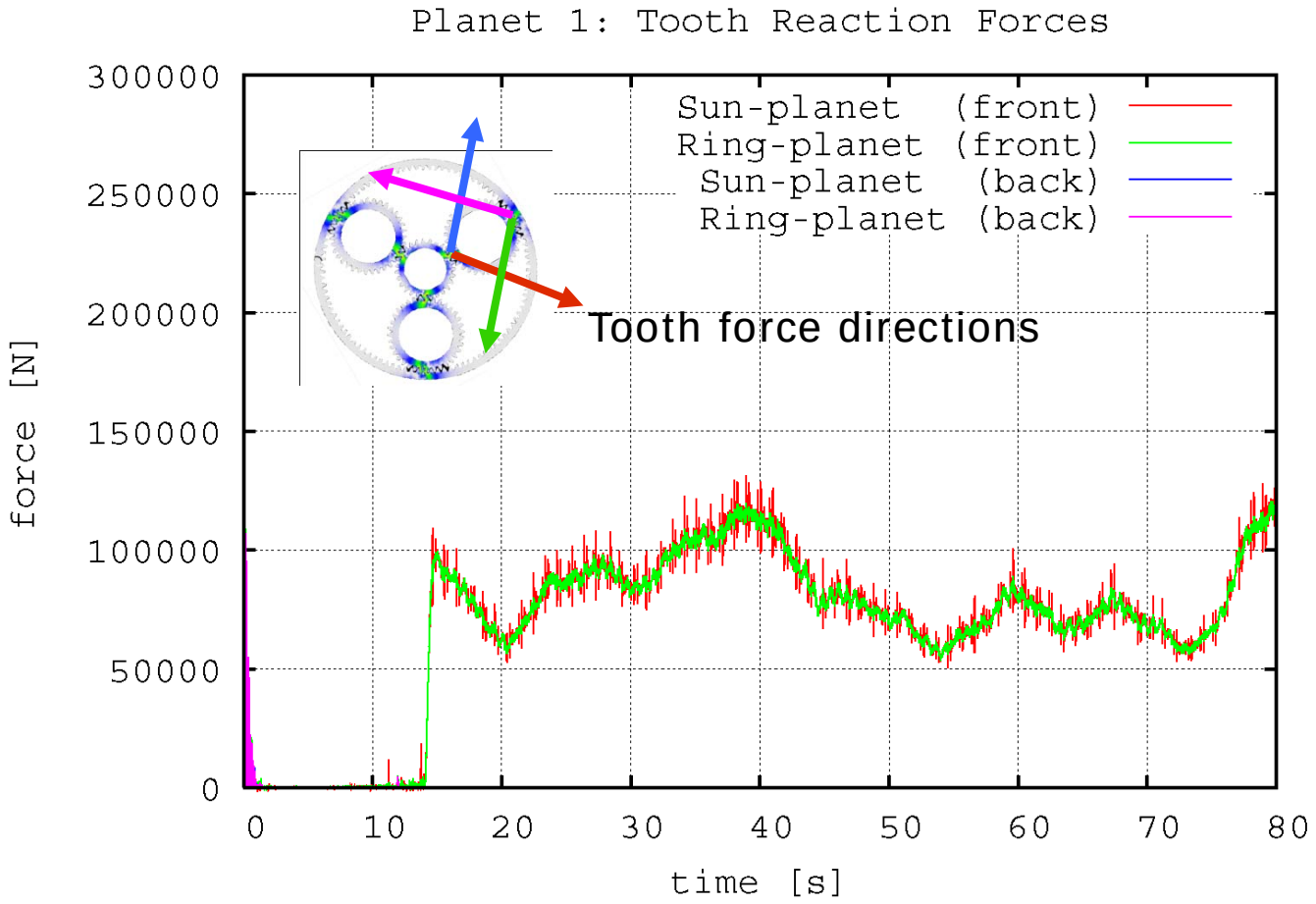


Simulated. No backlash



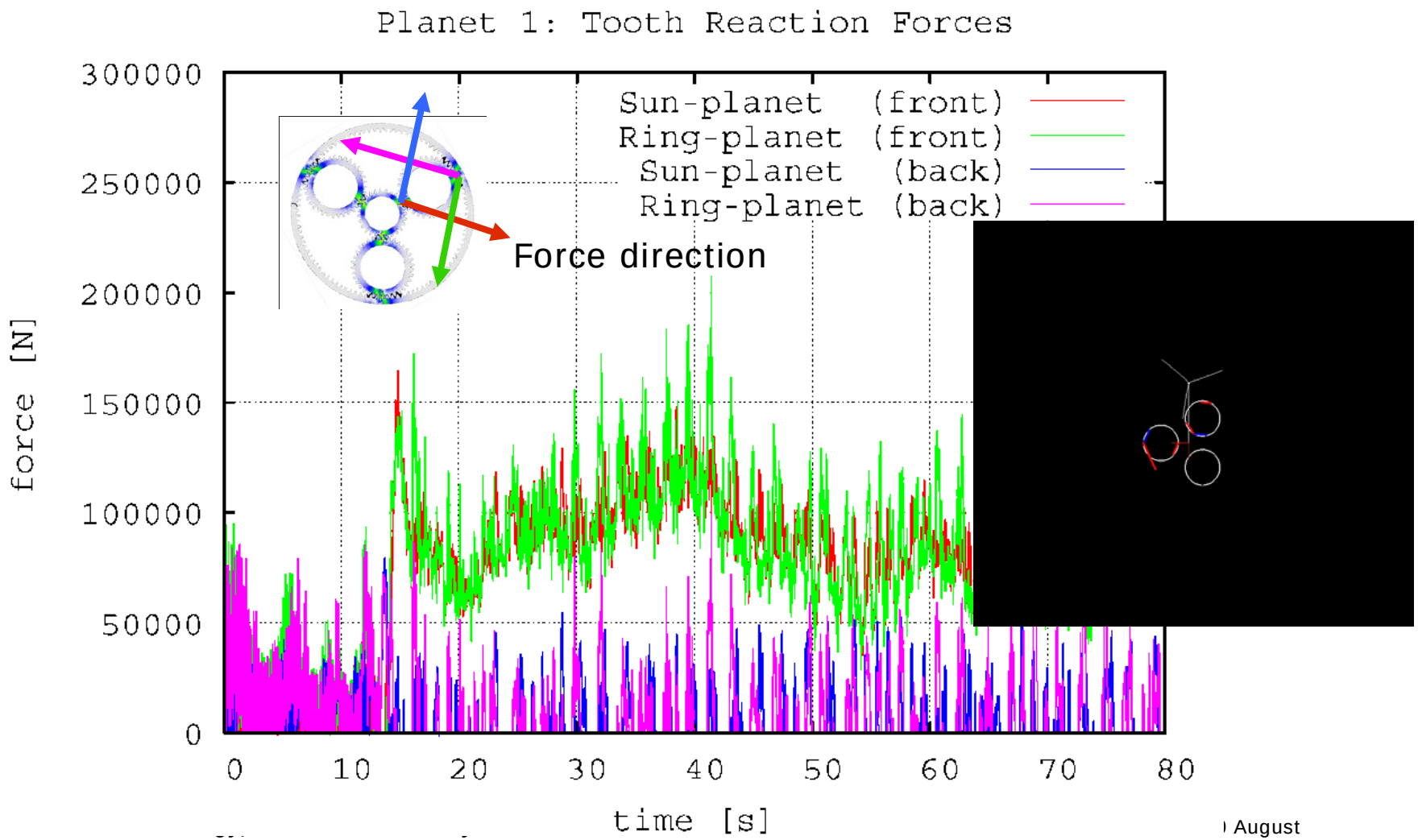
Tooth reaction forces in normal operation

HAWC2 time simulation at 10 m/s, 20 % turbulence



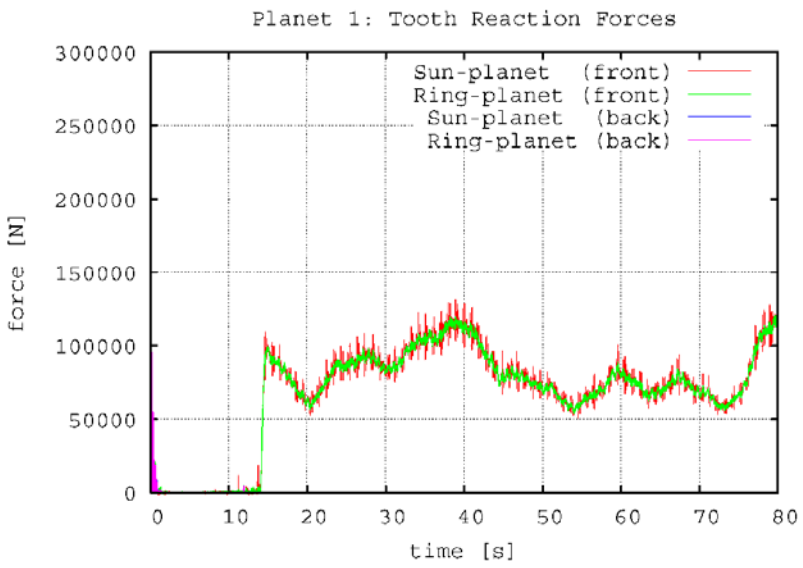
Tooth reaction forces during double contact

10 m/s, 20 % turbulence



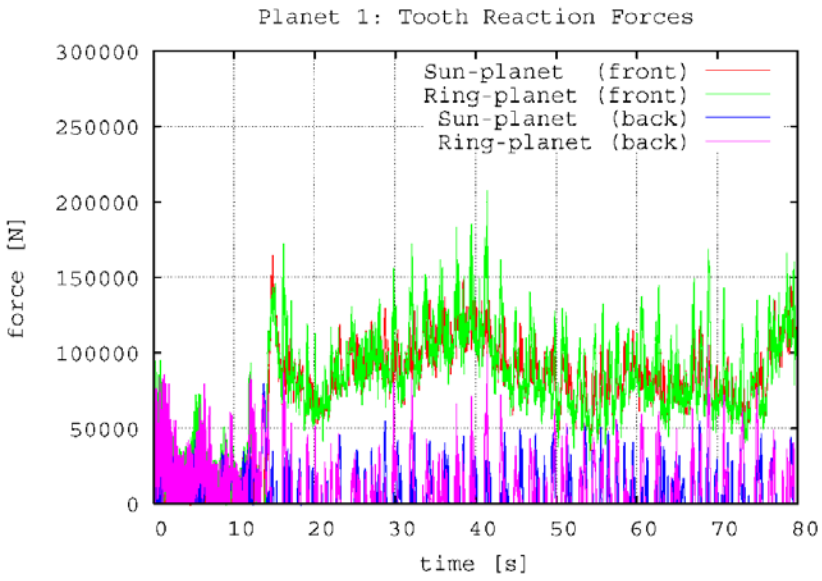
Tooth forces

Normal operation



Normal operation without double contact

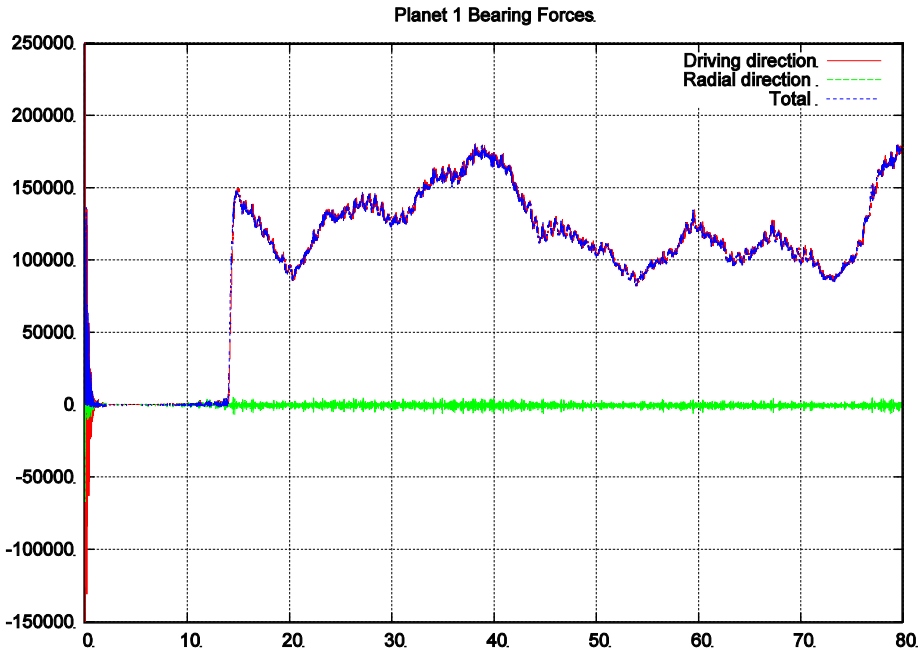
Double contact



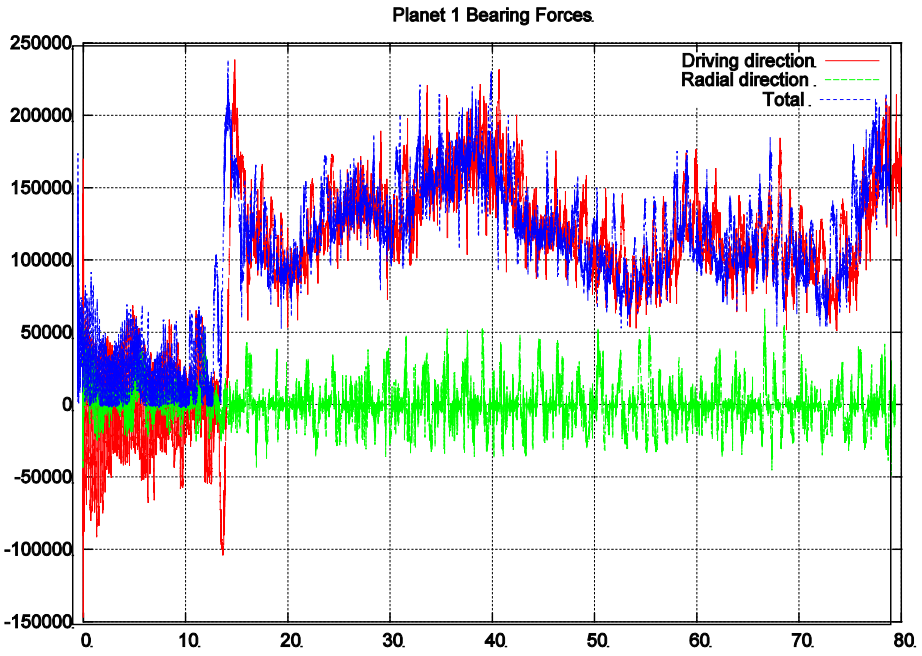
Large carrier bearing clearance causes double contact.
Loads are increased by~75 %.

Planet bearing forces

Normal operation

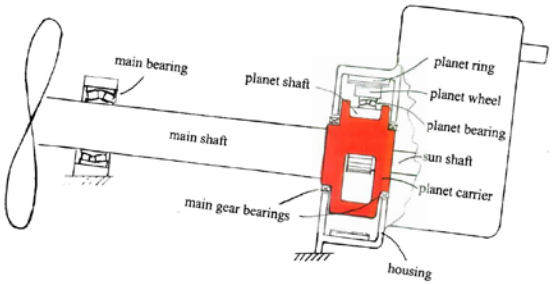


Double contact

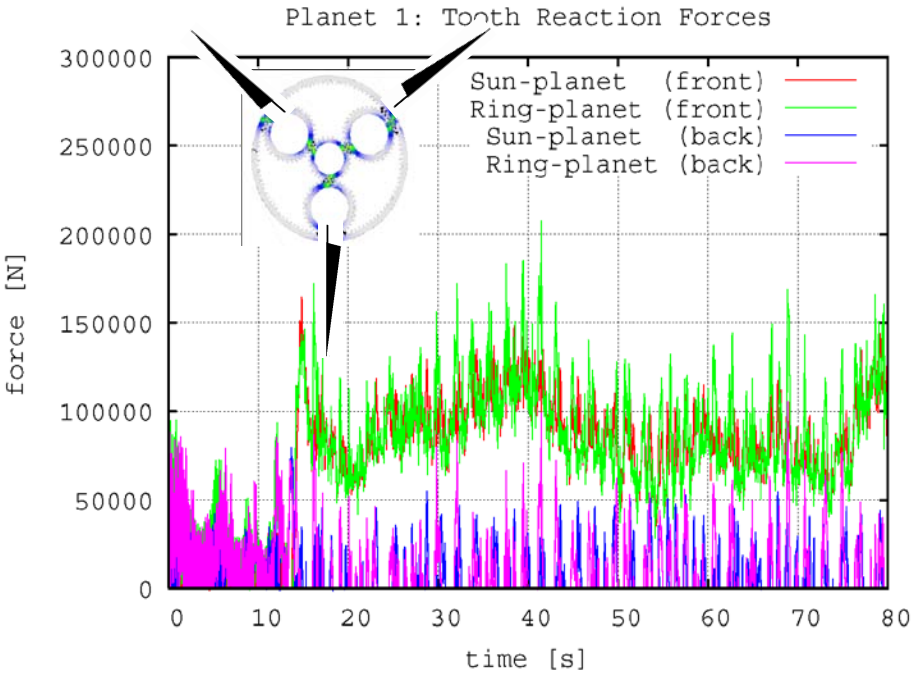


Radial forces are added app. directly to driving direction forces

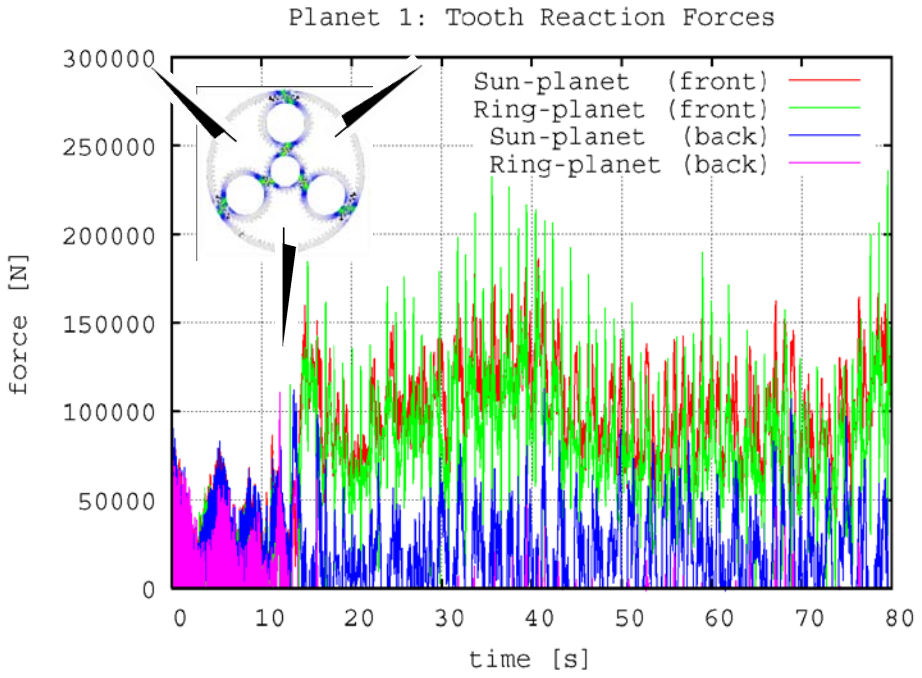
Tooth forces



Planets aligned with blades



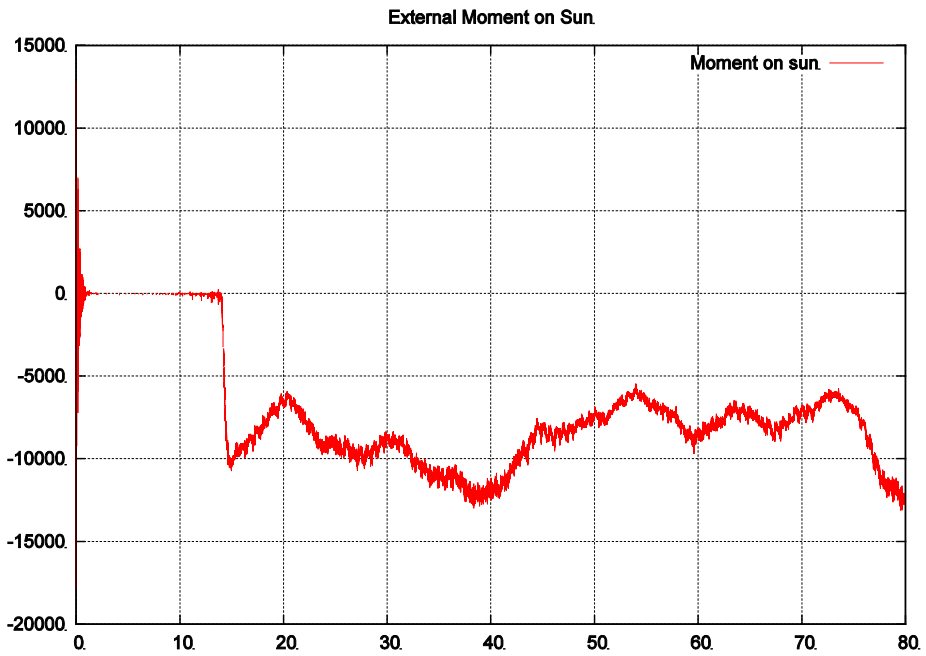
Planets rotated 60 degrees



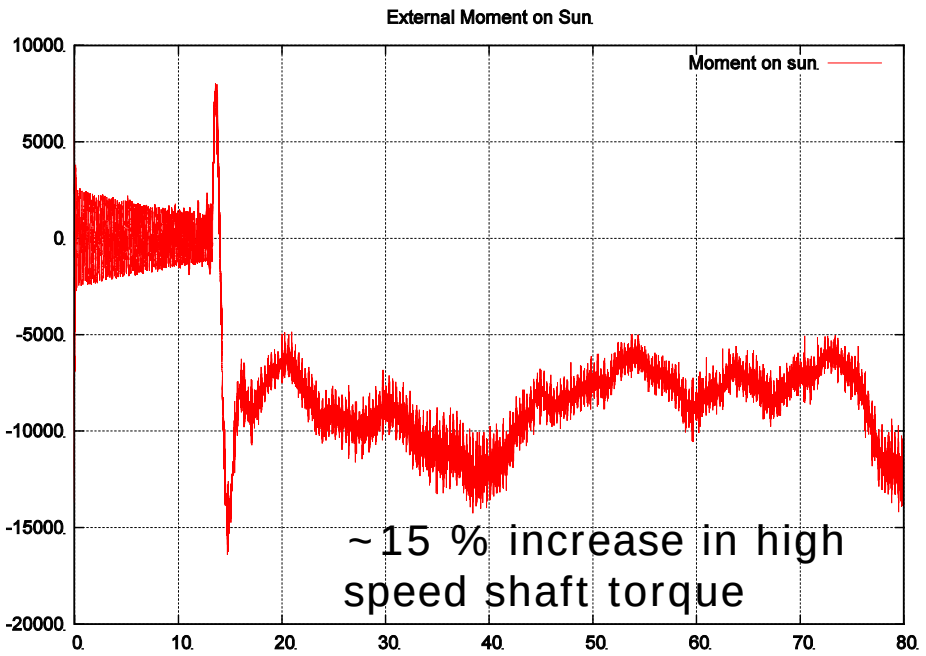
20 % increased loads

Sun torque with and without double contact

Normal operation



Double contact



During double contact:
Bending moment loads on the main shaft causes spikes on the sun torque and thus on the high speed shaft. ~15 % increase.

Summary

- Transient loads can occur internally in a planetary gear box

- if double contact occurs

- Tooth and planet bearing loads can increase with ~ 30 - 75 %
- The additional loads depend upon the relative rotational position of the planets and the blades. The difference in load could be 20 %
- The load variations are transferred to the sun and the high speed shaft
- High speed shaft spikes can increase by ~15 %
- The learning is easy: In order to avoid the problem, the planetary stage should be designed with sufficient backlash to avoid double contact due to deflection from any load condition and carrier bearing clearance
- The backlash associated with the occurrence of negative main shaft torque is, however, also an issue.